DECELERATION-LIMITING ROADWAY BARRIER

ORIGIN OF THE INVENTION

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CLAIM OF PRIORITY

This application claims priority from, and incorporates herein by reference, provisional application number 60/254,285, entitled "Energy Absorbing System," filed with the U.S. Patent and Trademark Office on December 6, 2000.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to barrier systems and, more particularly, to deceleration-limiting barrier systems for decelerating moving objects in a controlled manner.

Description of the Related Art

Various types of structures and mechanisms have been employed for decelerating or arresting moving objects. In particular, a number of protective barriers and energy dissipating mechanisms have been devised for arresting a moving vehicle.

At racetracks, for example, protective peripheral barrier walls (especially in the curved portions of the track) are frequently made of rigid materials such as reinforced

concrete for the purpose of containing a crash vehicle in order to prevent it from deviating from the raceway and colliding with other objects, or with spectators. Such rigid walls or barriers can cause dangerous levels of deceleration ("*G*" forces) that may kill or severely injure the driver. Similar results may occur with these rigid barriers on public highways where serious injury or death may result when a motorist deviates from the road and collides with a rigid barrier at high velocity.

Deformable barriers have been employed in some instances to help absorb some of the energy involved in a high-speed collision. For example, "barrel" barriers, which typically consist of several crushable 50-gallon drums positioned side-by-side, provide a degree of protection to vehicles and their occupants during an impact by increasing the distance through which the vehicle is decelerated. Other examples of deformable barriers include stacked vehicle tires and bales of hay. While deformable barriers can lessen the "*G*" forces involved in a crash, such barriers have generally provided sub-optimal impact absorption. Moreover, deformable barriers can create problems of their own, for example, by "catching" the vehicles that strike them tangentially, leading to more severe damage and injuries than would be the case had the vehicle been permitted to skid along the barrier. In addition, if the vehicle crashes into such a barrier at high speed and is not retained by the barrier, the crashed vehicle and attendant debris can be dangerously thrown back into the path of oncoming vehicles, or into the viewing stands.

Accordingly, there is a need for an improved roadway barrier system and, more specifically, a deceleration-limiting roadway barrier system for decelerating the vehicles in a controlled manner and for retaining moving vehicles that collide with the barrier system.

SUMMARY OF THE INVENTION

Embodiments of the invention provide a roadway barrier system and method for decelerating a moving vehicle in a controlled manner and for retaining the decelerated vehicle. A net or mesh of the roadway barrier system receives and captures the moving vehicle. The net or mesh is secured to anchors by energy absorbing straps. The energy absorbing straps deploy under a tensional load to decelerate the moving vehicle, the straps providing a controlled resistance to the tensional load over a predefined displacement or stroke to bring the moving vehicle to rest. Additional features include a sacrificial panel or sheet in front of the net that holds up the net or mesh while deflecting vehicles that collide only tangentially with the roadway barrier system.

In general, in one aspect, the invention is directed to a deceleration-limiting barrier comprising a net, anchors, and a flexible strip arranged to secure the net to the anchors. Portions of the strip are joined together in a manner so as to be susceptible to being pulled apart under a load that is less than a load capacity of the strip.

In general, in another aspect, the invention is directed to a barrier for limiting decelerating of a moving body. The barrier comprises means for receiving and retaining the moving body, means for anchoring the receiving and retaining means, and means for decelerating the moving body in a controlled manner to thereby limit the deceleration thereof to below a predefined maximum deceleration level.

In general, in yet another aspect, the invention is directed to a deceleration-limiting roadway barrier system. The roadway barrier system comprises a first row of barriers positioned end-to-end alongside a roadway, and a second row of barriers positioned end-to-end alongside the first row of barriers, the barriers of the first row being staggered from the

barriers of the second row. A plurality of anchors are fixedly mounted in the ground alongside the roadway. Each barrier comprises a net and one or more flexible strips arranged to secure the net to one or more anchors, with portions of each strip joined together in a manner as to be susceptible to being pulled apart under a load that is less than a load capacity of the strip.

In general, in still another aspect, the invention is directed to a method of decelerating a moving body. The method comprises receiving the moving body in a net, deploying a plurality of energy absorbing straps attached to the net, decelerating the moving body using the energy absorbing straps, and limiting the deceleration of the moving body to below a predefined maximum deceleration level.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the system and method of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

Figures 1A-1C illustrate an energy absorbing strap according to some embodiments of the invention;

Figures 2A-2B illustrate the load that can be absorbed by a loop of the energy absorbing strap according to some embodiments of the invention;

Figures 3A-3B illustrate the load that can be absorbed by multiple loops of the energy absorbing strap according to some embodiments of the invention;

Figures 4A-4B illustrate the energy absorbing strap attached to a net according to some embodiments of the invention;

Figure 5 illustrates a deceleration-limiting barrier according to some embodiments of the invention;

Figures 6A-6B illustrate the deceleration-limiting barrier secured to an anchor according to some embodiments of the invention;

Figures 7 illustrates a deceleration-limiting roadway barrier system according to some embodiments of the invention;

Figures 8A-8D illustrate a progressive view of a vehicular crash into the deceleration-limiting roadway barrier system according to some embodiments of the invention; and

Figure 9 illustrates a flow chart of a method of decelerating a moving body according to some embodiments of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Following is a detailed description of the drawings wherein reference numerals for similar components and elements are carried forward.

As mentioned previously, embodiments of the invention provide a deceleration-limiting roadway barrier system and method for retaining and decelerating a moving vehicle. The roadway barrier system is designed to limit the amount of deceleration or *G* force experienced by the moving vehicle to a certain preset level, regardless of how fast the vehicle is traveling at the time of impact. In other words, a faster traveling vehicle will not experience more severe deceleration than a slower traveling vehicle; both vehicles will experience about the same level of deceleration regardless of their respective speeds. The

specific deceleration level may be set at a certain maximum as needed to safely bring the vehicles and the occupants therein to a complete stop.

In some embodiments, the deceleration-limiting roadway barrier system comprises two parallel rows of barriers alongside a roadway or racetrack. The barriers in each row are placed end-to-end along the roadway or racetrack, with the barriers in one row staggered relative to the barriers in the other row. Each barrier is anchored to the ground by ground anchors and includes a net and a flexible, energy absorbing strip arranged so as to secure the net to the anchors. Portions of the flexible strip may be joined to each other in a manner such that the joined portions may be pulled apart under a load which is less than the load capacity of the strip.

Figure 1A through Figure 7 is a sequence of sketches that, when taken as a whole, illustrate the construction of a deceleration-limiting roadway barrier system, beginning with the formation of energy absorbing straps and leading up to the assembly of deceleration-limiting barriers and to the installment of those barriers in a roadway barrier system.

Referring now to Figures 1A-1B, an energy absorbing line, strip, or strap 10 is shown. The energy absorbing strap 10 is preferably made of a flexible material having a high tensile strength such as Kevlar™ or Nylon™. In some embodiments, the energy absorbing strap 10 may be folded or otherwise arranged to form a loop 12 in the strap 10. The inner surface of the loop 12 may then be stitched or otherwise joined together with fasteners 14, as disclosed in U.S. Patent Nos. 5,071,091 and 6,206,155, entitled "Load Limiting Energy Absorbing Lightweight Debris Catcher" and "Energy Absorbing Protective Shroud," respectively, which patents are hereby incorporated by reference.

The fasteners 14 of the loop 12 may be made of threads, cords, or other suitable fasteners, and are selected to have a lower tensile strength than that of the strap 10. The tensile strength of the fasteners 14 and, in part, the pattern in which they are stitched, determine the load required to pull apart the loop 12. It is important that this load be below the load capacity of the strap 10, preferably by at least a certain percentage. Thus, when a load is applied to the strap 10, the fasteners 14 will break or rip away to allow the loop 12 to be pulled apart. In effect, the load on the strap 10 is transferred to the fasteners 14 where it is absorbed and dissipated when the fasteners 14 break and rip away. The load capacity of the strap 10 will therefore not be reached or exceeded regardless of how large a load is applied provided there are enough fasteners 14 in the loop 12 to absorb the load.

It should be noted that, although the term "loop" is used herein, in general, any portion of the energy absorbing strap 10 may be joined to any other portion or portions of the strap 10 regardless of whether a "loop" is formed. Thus, in addition to a loop 12 being formed in the energy absorbing strap 10, a figure "S" shape, for example, or some other configuration may also be formed and stitched together in the strap 10.

Figure 1C illustrates a close-up view of a front face of the loop 12 formed in the energy absorbing strap 10. As can be seen, one or more rows of fasteners 14 (e.g., threads or cords) may be stitched into the loop 12 longitudinally along the loop 12, or laterally across the loop 12, or a combination of both, or some other pattern (e.g., diagonally). Depending on the spacing of the rows, the longitudinal stitches may provide a somewhat smoother and more continuous release than the lateral stitches as the loop 12 is pulled apart. Where lateral rows of stitches are used, the fasteners 14 are designed so as to break or rip away an entire row at a time as the loop 12 is pulled apart.

The energy absorbing characteristic of the strap 10 is illustrated in Figures 2A-2B, wherein *Fs* represents the load capacity of the strap 10, *Fr* represents the load at which the loop 12 will be pulled apart, and *Xm* represents the stroke or displacement provided by the loop 12. In general, *Xm* is equal to the length of the joined or stitched portions of the loop 12, which may be the entire loop 12 or only a portion thereof. As can be seen in the graph of load *F* versus displacement *X*, the moment that the load reaches *Fr*, the loop 12 is pulled apart as the fasteners 14 begin to break and rip away. The loop 12 continues to be pulled apart at approximately *Fr* (shown by the jagged line) as the fasteners 14 break and rip away under the stress of the load. Thus, the load is maintained near *Fr* because the instant it exceeds *Fr* by any substantial amount, more fasteners 14 will break or rip away, and the loop 12 is pulled further apart. This process continues until there is no longer a loop 12 (i.e., when $X = Xm$) or until the load has been sufficiently absorbed. Therefore, the strap 10 will not break regardless of the magnitude of the applied load because the maximum load that is actually placed on the strap 10 will be below its load capacity *Fs* as long as the stroke *Xm* of the loop 12 is sufficiently large. The total load absorbed by the loop 12 may be expressed by Equation (1):

$$Load = Fr \cdot Xm \tag{1}$$

Note that, although the total absorbed load depends on both the *Fr* and *Xm* terms, the rate of absorption (i.e., how fast the load is absorbed) depends primarily on the *Fr* term. For purposes of the roadway barrier system of the present invention, a lower *Fr* translates to a more gentle deceleration, which will necessitate a larger stroke *Xm*, and vice versa.

Figures 3A-3B illustrate a deceleration-limiting lanyard 30 that may be used in the roadway barrier system according to some embodiments of the invention. As can be seen,

the deceleration-limiting lanyard 30 has multiple loops 12 formed therein instead of just one. The multiple loops 12 may be formed by connecting several single-loop energy absorbing straps together in series, or by forming several loops 12 in one energy absorbing strap, or a combination of both. In any case, the load capacity of the lanyard 30 is the sum of the load capacity of each loop 12 in the lanyard 30. This load capacity may be expressed by Equation (2):

$$Load = Fr \cdot (Xm1 + Xm2 + Xm3 + \ldots + Xmi) \qquad (2)$$

where the sum of *Xm1*, *Xm2*, *Xm3*, ... , *Xmi* represent the total stroke provided by the individual loops 12 in the lanyard 30. Note that every loop 12 may have the same stroke *Xm*, or one or more loops 12 may have a different stroke *Xm*, depending on the requirements of the particular application.

In some embodiments, each loop 12 of the lanyard 30 may be designed so as to be pulled apart under the same load *Fr*, thereby providing the lanyard 30 with a substantially constant level of deceleration. Thus, regardless of the velocity of the vehicle (e.g., 50, 100, or 150 mph) at the time of impact with the roadway barrier system, the deceleration of the vehicle will be limited to some constant, preselected level. The higher velocity will, of course, require a longer stroke or displacement *Xm* to decelerate.

In other embodiments, however, one or more of the loops 12 may be designed so as to require a different (e.g., greater or lesser) load to pull these loops apart, so long as all or most of the loops can be pulled apart with a load *Fr* that is lower than the load capacity *Fs* of the lanyard 30. For example, the first loop may be designed to be pulled apart under a load *Fr1* which is less than a load *Fr2* required to pull apart the next loop, and so on in the series of loops. Thus, the lanyard 30 may provide a gentle deceleration initially as the weaker

loops are pulled apart first, then increased deceleration as the stronger loops are pulled apart later. Such an arrangement may be useful where there is limited space available for bringing the vehicle to rest. As the vehicle approaches the end of the available space, the stronger loops can provide increased deceleration to quickly bring the vehicle to rest.

Turning now to Figure 4A, in some embodiments, the roadway barrier system of the present invention includes a high strength capture mesh or net 40. The net 40 may be a simple, ordinary net that, like the lanyards 30, is made of a flexible high-strength material such as Kevlar™ or Nylon™. Each of the opposing end portions of the net 40 may be attached, tied, connected, or otherwise secured by one or more lanyards 30 to an anchor (shown in Figure 6). Alternatively, multiple lanyards 30 may be used in parallel, depending on the load capacity required.

In some embodiments, the lanyards 30 may be connected to the net 40 via load lines 42 that are also made of a high-strength material such as Kevlar™ or Nylon™. Figure 4B shows a close-up view of the load lines 42 of the net 40 being secured to the lanyards 30 through an optional load ring 44. As can be seen, each of the lanyards 30 and the load line 42 are routed through the load ring 44 to provide a secure connection between the lanyards 30 and the load line 42.

Figure 5 is an exploded view of a deceleration-limiting barrier 50 according to some embodiments of the invention. The barrier 50 includes a front sacrificial panel 52 that can be used to hold up the net 40. In some cases, the barrier 50 may also include a back sacrificial panel 54 that is used together with the front sacrificial panel 52 to hold up the net 40. The front sacrificial panel 52 may be made of a thin layer of epoxy, concrete, plywood, or other

similar material that can be broken apart upon impact, and the back sacrificial panel 54 may be made of the same material or an even lighter material such as a foam material.

During assembly of the barrier 50, the lanyards 30 and the load lines 42 are folded or otherwise tucked onto the net 40, as shown, such that only the loose ends of the lanyards 30 are exposed. This assembly is then sandwiched between the front and back sacrificial panels 52 and 54 for support. The entire assembly may then be sealed, glued, or otherwise adhered together into a single barrier 50.

The assembled barrier 50 may then be attached, tied, connected, or otherwise secured via the ends of the lanyards 30 to ground anchors 60, as shown in Figures 6A-6B. The ground anchors 60 may be, for example, blocks of concrete, steel, or other heavy material, and may be embedded in or otherwise secured to the ground with sufficient strength to support an impact with a high speed vehicle. In some embodiments, each of the ground anchors 60 may be constructed with an eyehook bolt 62 embedded in a concrete cone 68, with a washer 64 and a nut 66 to secure the eyehook bolt 62 in the cone 68.

Figure 7 illustrates a plurality of barriers 50 placed end-to-end and anchored by the ground anchors 60 to form a deceleration-limiting roadway barrier system 70. Such a roadway barrier system 70 may be installed alongside a racetrack or a roadway, according to some embodiments of the invention, to prevents spectators and pedestrians from entering the racetrack or roadway, and to keeps cars and other vehicles from leaving the racetrack or roadway. In some embodiments, the barriers 50 are arranged in a first row 72 and a second row 74, with each row being fully capable of decelerating a vehicle independently of the other row. The barriers 50 in the first row 72 are staggered relative to the barriers 50 in the second row 74, as shown, such that no two barriers are in register. Such an arrangement

ensures that a vehicle that happens to collide at a junction 76 between two barriers in one of the rows and possibly splitting the two barriers will still be fully captured by a barrier in the other row.

In some embodiments the junction 76 between two barriers 50 may be in the form of a joint such as a tongue-and-grove joint or a dovetail joint (not expressly shown). The barriers may each have male portions and female portions to facilitate the quick removal and replacement of the barriers 50. Such joints allow the barriers to simply be slid in and out of connection with other barriers. For this purpose, a supply of barriers 50 may be made readily available in a nearby storage area (e.g., a warehouse) to replace used barriers as needed.

A supporting pole, pipe, or shaft 78 made of rigid, but easily shattered material such as wood, aluminum, PVC, or other suitable material may be spaced at various points along the roadway barrier system 70 to provide vertical support the first and second rows 72 and 74, respectively, of the roadway barrier system 70. Other suitable structures such as L-shaped brackets or braces may also be used to support the first and second rows 72 and 74.

Figures 8A-8D illustrate a vehicle crashing into one of the barriers 50 of the deceleration-limiting roadway barrier system 70. As the vehicle crashes into the barrier 50, the sacrificial panels and any supporting poles are broken away, and the vehicle is captured in the net 40. The forward momentum of the vehicle carries the net 40 forward and causes the lanyards attached thereto to be deployed. The lanyards, which are anchored by the ground anchors, operate to decelerate the vehicle and bring it to rest by absorbing the energy of the vehicle in the manner described above. Such an arrangement limits the maximum level of deceleration or G force experienced by the occupants of the vehicle to near some preset level no matter how fast the vehicle is traveling. In other words, the level of

deceleration will be the same whether the vehicle impacts the barrier at 100 mph, 200 mph, or some other speed. Higher velocities, of course, will require a longer stopping distances. The maximum level of deceleration may be selected as needed to suit a particular application.

In some embodiments, the front sacrificial panel (see Figure 5) of each barrier 50 are designed to withstand low level glancing impacts and bumps from vehicles that are usually encountered many times during a racing event or normal roadway traffic. In other words, the front sacrificial panel may be designed so that a breakup occurs only when a significant impact is encountered. For this purpose, the front sacrificial panel may have a smooth surface on the side facing the racetrack or roadway such that vehicles making a low level impact with the barrier 50 are simply deflected and allowed to continue.

Figure 9 illustrates a method 90 of decelerating a moving object such as a vehicle. The method begins at step 91 when an object crashes or is otherwise received in a load-limiting barrier such as the deceleration-limiting barrier of the present invention. At step 92, the energy absorbing straps or lanyards of the barrier are deployed to decelerate the object. At step 93, the object is decelerated at a substantially constant deceleration by the energy absorbing straps or lanyards of the deceleration-limiting barrier system of the present invention. Finally, at step 94, the object is brought to rest after the energy thereof has been absorbed by the barrier system.

While a limited number of embodiments of the invention have been described, these embodiments are not intended to limit the scope of the invention as otherwise described and claimed herein. Variations and modifications from the described embodiments exist. For example, in some embodiments, the capture net may be a sheet instead of a net.

Furthermore, in some embodiments, the loops in the energy absorbing strap may be bonded, adhered, or formed using Velcro™ instead of stitches to alleviate puncturing of the strap and thereby render the strap more amenable to reuse. Accordingly, the appended claims are intended to cover all such variations and modifications as falling within the scope of the invention.